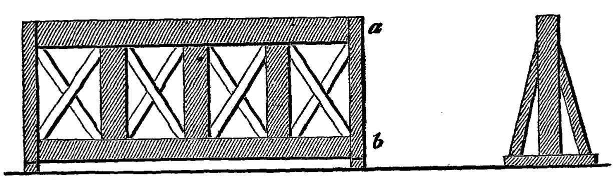
The case in which this clock is mounted is composed of slate slabs, the back being a single slab $1\frac{1}{4}$ inches thick, and to this the pendulum is suspended independent of the rest of the clock. The weight and rigidity of the slate give it great stability, and the clock goes with great steadiness, is very readily adjusted; and if a minimum of friction be a desideratum, I think this mode of construction possesses it more than any other.

On Sympathetic Influence between Clocks. By William Ellis, Esq. of the Royal Observatory, Greenwich.

It has been stated by clockmakers that clocks, if placed near together on the same wall or other support, will mutually influence each other, and in vol. xli. of the *Philosophical Transactions* there are two papers by Ellicott, giving an account of the "influence which two pendulum clocks were observed to have upon each other." Lately, however, having to test a number of clocks at the Royal Observatory, provided for use in the observations to be made of the Transit of *Venus* in the year 1874, some curious instances of sympathetic influence came accidentally under my own notice, concerning which the Astronomer Royal has requested me to draw up for presentation to the Royal Astronomical Society, a statement of the facts observed, since they appear to possess sufficient interest to make their publication desirable.

In order conveniently to rate at the Royal Observatory the clocks alluded to, a large and stout wooden stand was constructed, about eleven feet long and five feet high, along both sides of which the clocks could be ranged side by side. The stand is of the annexed form. The cross bracing (distinguished in the side



Side view.

End view of one of the end standards.

view by not being shaded) was not at first supplied, and it was without these bracings that the stand was first used. Each clock-case was firmly screwed both to the upper and lower horizontal bars of the stand (*a* and *b* of the side-view sketch). When rating was commenced, two clocks only had been fixed, "Graham, No. 2," and "Arnold, No. 2," and it was soon remarked that there existed sympathetic influence, the difference between the times indicated by the two clocks remaining day after day constant. They were rated from 1872, May 2 to May 21, and an abstract of the rating is given in the following table:—

1872.	Graham 2 fast of Sidereal Time.	Arnold 2 fast of Sidereal Time.	Graham 2 fast of Arnold 2.
	m s	m s	s
May 2	3 44·6	3 41·5	3·1
11	3 52·2	3 49·1	3·1
18	3 40·9	3 36·9	4·0
20	3 40·9	3 37·6	3·3
21	3 41·5	3 38·3	3·2
1	2	3	4

The numbers in column 4 show that the difference between the clocks was the same ($3^{s}\cdot1$) on May 11 as on May 2, comparisons on intermediate days, not inserted in the table, showing that this difference remained during the nine days constant. The clocks both gained in the same period $7^{s}\cdot6$, or $0^{s}\cdot84$ daily, and as the pendulum of one clock swung to the left, that of the other went to the right.

Now on May 11 the clock Graham 2 was stopped. The rate of Arnold 2 immediately changed considerably. Between May 11 and May 18 it lost $12^{s}\cdot2$, or $1^{s}\cdot74$ daily, or its daily rate changed, on the stoppage of Graham 2, from $0^{s}\cdot84$ gaining to $1^{s}\cdot74$ losing, that is, it *increased its losing rate by* $2^{s}\cdot58$.

On May 18 the clock Graham 2 was again set going, but with its pendulum swinging now in the *same* direction as that of Arnold 2. That this was done is seen by the difference (in column 4 of the table) which was left $4^{s}\cdot0$ instead of $3^{s}\cdot1$. But on May 20 this difference of $4^{s}\cdot0$ had become lessened to $3^{s}\cdot3$, and on May 21 to $3^{s}\cdot2$, showing approach of the pendulums to their former relative positions. The *rate* of Arnold 2 correspondingly returned to its former value: between May 18 and 20 it was $0^{s}\cdot35$ gaining, but between May 20 and 21 it had become $0^{s}\cdot7$ gaining. Or, the starting of the clock Graham 2 changed the daily rate of Arnold 2 from $1^{s}\cdot74$ losing to $0^{s}\cdot7$ gaining, that is, it *decreased its losing rate by* $2^{s}\cdot44$. Thus a change of rate was produced in the clock Arnold 2 by the starting of Graham 2, in the opposite direction, and of nearly precisely the same amount as that produced by the stoppage of Graham 2. (Neither of the two clocks, on the starting of Graham 2 on May 18, took up its former rate at once, because of the disturbing effect introduced by setting the pendulum of Graham 2 into an opposite position relatively to that of Arnold 2, as mentioned. But between May 20 and 21 the clocks had about returned to their former state; the difference having become $3^{s}\cdot2$ as compared with $3^{s}\cdot1$, and the rate, $0^{s}\cdot6$ gaining for Graham 2, and $0^{s}\cdot7$ gaining for Arnold 2, as compared with $0^{s}\cdot84$ gaining. The rating was discontinued on May 21.)

The wooden frame was now strengthened by the addition of the cross bracing before spoken of. On further trial of the clocks, no further disturbing effects (as indicated by the clock rates) were perceived. Many other clocks were afterwards fixed to the stand,

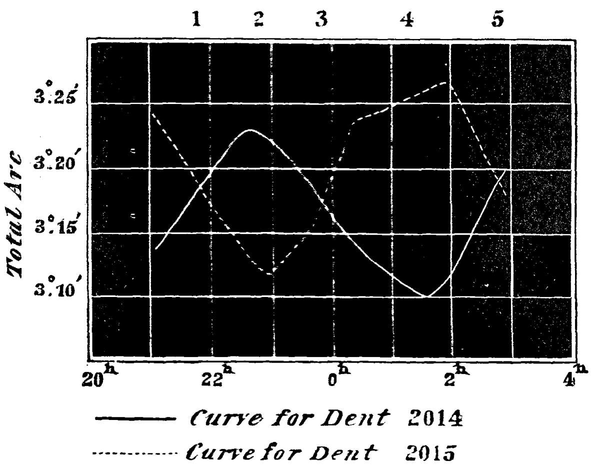
and these, with others mounted each on a separate stand, were simultaneously rated. Judging by their rates, all these clocks performed satisfactorily. But in the course of time it became evident that, whilst the arcs of vibration of the pendulums of *all* the clocks on separate stands were very uniform, those of *all* the clocks on the great stand (at this time nine in number) showed great variations, indicating that sympathetic influence still appeared to exist, although the effect was not now perceptible in the rates. To investigate this, all the clocks on the great stand were for a week stopped, excepting one, and during this week its pendulum maintained a nearly constant arc. The same thing was done as regards another of the clocks, with a like result. The clocks were then all set going again, and observations of the arcs of three of them made at frequent intervals: one of the clocks selected having an extreme losing rate, one an extreme gaining rate, and the other a rate intermediate between those of the other two. The observations are contained in the following table:—

1873.				Dent 2014 Daily Rate $8^s \cdot 3$ losing.	Dent 2011 Daily Rate $4^s \cdot 1$ losing. Total arc of vibration.	Dent 2015 Daily Rate $1^s \cdot 5$ gaining.
	d	h	m	° ′	° ′	° ′
Feb.	27	21	45	2 57	3 53	3 19
		22	45	3 7	3 47	3 9
		23	0	3 9	3 45	3 9
		23	15	3 12	3 42	3 10
		23	30	3 15	3 41	3 11
		23	45	3 14	3 35	3 15
	28	0	45	3 8	3 21	3 29
		1	15	3 5	3 15	3 31
		1	45	3 1	3 10	3 29

These numbers show that the arcs of vibration were in a state of rapid change, in nature periodical, but that the effect produced by the disturbing action was different in each clock. To study the action more simply, all the clocks were now stopped excepting two, Dent 2014 and 2015, and the following observations made:—

1873.				Dent 2014 Daily Rate $8^s \cdot 1$ losing. Total arc of vibration.	Dent 2015 Daily Rate $1^s \cdot 4$ gaining.
	d	h	m	° ′	° ′
March	4	21	10	3 14	3 24
		22	30	3 23	3 14
		22	50	3 23	3 12
		23	40	3 19	3 16
	5	0	25	3 14	3 24
		1	35	3 10	3 26
		2	0	3 12	3 27
		2	50	3 20	3 18

The relative change of arc is better seen in the following diagram:—



At the point 2 the two pendulums were swinging simultaneously in opposite directions, and at the point 4 in the same direction, or at the point 4 the pendulum of the clock 2015 had advanced $1^{s}\cdot 0$ on that of 2014. Consequently between the points 1 and 5 the pendulum of 2015 had advanced $2^{s}\cdot 0$ on that of 2014; the interval occupied in making this advance being, according to the time scale of the diagram, from about $21^{h}\ 50^{m}$ to $2^{h}\ 45^{m}$, or about $4^{h}\ 55^{m}$.* Now, by the observed rates, given in the last preceding table, it will be seen that the clock 2015 was gaining $9^{s}\cdot 5$ daily on 2014; it should, therefore, advance $2^{s}\cdot 0$ on 2014, in $24^{h} \times \frac{2}{9\cdot 5}$, or $5^{h}\ 3^{m}$, which result differs by a few minutes only from that found from the diagram. In this mutual action of two pendulums there is another circumstance to be remarked, which is that, in the alternate variations of arc, as one pendulum attained its *greatest* arc, the other reached its *least* arc.

This simple experiment with two clocks shows clearly the dependence, in a case of mutual disturbance, of the variations of arc on the difference of rate, the period in which in each clock the arc goes once through all its changes corresponding to the advance of one pendulum on the other by one complete vibration (or 2^{s}).

It appears, therefore, that the pendulums of two clocks, fixed to the same support, tend to influence each other, in degree, according to the facility with which the support can be put into or communicate vibration, and further, that

* A little inequality is introduced into the diagram from the fact of the mean value of arc for Dent 2015 being a little greater than that for 2014. In strictness the dotted curve should be lowered by about 4′, which would shift the points of intersection 1 and 5 a little to the left, and the point 3 a little to the right, thereby rendering the spaces between the several points equal, without affecting the absolute distance between the points 1 and 5.

(1) The influence may be imperceptible to ordinary methods of observation ;

(2) Or may be perceptible only as affecting the arcs of vibration in a lesser or greater degree ;

(3) Or may be sufficiently powerful to cause the clocks to move entirely in sympathy.

In the practical use of clocks, cases (1) and (3) will never cause error ; in the one instance no injurious effect would be produced, and in the other the effect would soon be perceived. But not so with case (2). For the variations of arc would usually cause small alternate accelerations and retardations in the time, which, in the daily rating of an ordinary clock, might not be distinguished or separated from other greater sources of error (as was the case with the Transit of *Venus* clocks, after bracing the wooden stand, on which they were temporarily placed for trial, as before mentioned). No doubt, however, if a clock, supposed to be so influenced, were compared very frequently, by some accurate method, with another independent clock (suppose by coincidence of beats, using an intermediate chronometer), the inequality of rate would then be perceived. Such inequalities, even if small in magnitude, being of periodical character, might affect injuriously any delicate experiment, and would be especially mischievous in any clock used for very accurate or fundamental work. Examination of the arc would, however, always reveal the existence of disturbance.

Some apology may be necessary for the length of this paper, but I have thought that, in a matter of experiment of this kind, it was desirable to give an account of the phenomena observed in some detail.

Royal Observatory, Greenwich,
1873, *June* 10.

On a Recording Micrometer. By W. H. M. Christie, Esq.

In observations of zenith distance with a meridian instrument it is of great importance to secure several bisections of a star during its passage across the field, and also to have a permanent record of the corresponding micrometer-readings for correction of the mistakes which no doubt often occur. To secure both of these objects without throwing any more work on the micrometer-screw, or in any way interfering with its action, there seems to me nothing so simple as putting a thin cylinder covered with paper on the micrometer head and making punctures on it ; but some plan must be adopted for distinguishing the punctures corresponding to the several bisections of the same object, and also those corresponding to any particular object from others previously made. I would suggest two arrangements for this, the latter of which is more complete, but at the same time probably rather too complicated for general use.